THE

HOT SPRINGS AND GEYSERS

OF THE

YELLOWSTONE AND FIREHOLE RIVERS.

BY F. V. HAYDEN.

(Published by permission of the Secretary of the Interior.)

[From the American Journal of Science and Arts, Vol. III, Feb. and March, 1872.]

[From the American Journal of Science and Arts, Vol. III, Feb., 1872.]

THE HOT SPRINGS AND GEYSERS OF THE YELLOWSTONE AND FIREHOLE RIVERS.

By F. V. HAYDEN.

With Maps.

(Published by permission of the Secretary of the Interior.)

We shall not attempt in this article to do more than to give a brief description of the hot springs and geysers of this wonderland. Their origin does not differ from that of similar springs which have been so often described in Iceland, New Zealand, and on a small scale in other portions of the world. But it was not until comparatively recent date that it was known that such a wonderful region existed in our own country. For eighteen years past the writer has heard various accounts from Indians, trappers, guides, &c., of the singular spouting springs and mountains of sulphur in the vicinity of the Yellowstone Lake; but the difficulties of access to an unknown country, and its remoteness from settlements, have prevented an examination of the region by competent persons. The party under the command of Col. Wm. F. Reynolds, U. S. Engineers, in 1859 and '60, endeavored to enter the Basin by way of the Wind River Mountains, but failed on account of the ruggedness of the mountains and the depth of snow. Our guide, Mr. James Bridger, the best mountain man the West has ever produced, was quite familiar with the country, and frequently entertained us with marvelous descriptions of the wonders of that great Basin. The rapid settlement of Montana has now rendered it an easy matter to explore this strange region; and last year Gen. Washburn and party, escorted by Lieut. Doane, U. S. A., gave us the first glowing and impressive accounts of the country.

Before entering upon a description of the hot springs, it may be well to present a brief summary of the principal geological features of the Yellowstone Basin. We may remark at once that nine-tenths of the area is covered with volcanic material in some form. The basis rocks are the usual metamorphic granitoid series of the country, with basalts and basaltic conglomerates in every variety. The sedimentary rocks belong to the Carboniferous, Jurassic, Cretaceous and Tertiary ages.

It is doubtful whether any unchanged rocks older than the Carboniferous occur there. The Triassic is probably wanting. The sedimentary rocks occur in patches, covering very restricted areas, yet presenting evidence that, up to the period of the Eocene Tertiary inclusive, they once extended uninterruptedly over all the country. In the Yellowstone valley, as in the valleys of all the streams of the West, there is a chain of lake basins that must have existed during the Pliocene period. Below the first cañon near the mouth of Shields river, there is one of these basins ten miles long, and on an average four miles wide. Between the first and second cañons there is a basin about 20 miles long, and on an average four miles in width, with the modern Pliocene marls and sands covered by a floor of basalt in some places. There was a continuous chain of these lakes, of greater or less size, to the source of the river; thence it expanded out into an immense double lake, of which only a remnant now remains. The Yellowstone Lake is now about 22 miles in length from north to south, and has an average width of about 10 or 15 miles from east to west. This lake was once much larger than at present, and it was partially connected with another lake about 30 miles long and 20 wide, which terminated at the commencement of the Grand Cañon, at the Upper Falls of the Yellowstone.

Warm springs are not uncommon in the valley of the lower Yellowstone, but the temperature is seldom higher than 60° or 80°. It is not until we reach the Gardiner's river, a small branch flowing into the Yellowstone from the west side, that the true hot springs commence in their full force. This point is located about midway between the second cañon and the Grand Cañon opposite the third cañon. In ascending the Yellowstone valley, our trail left the main river and turned up the valley of Gardiner's creek. About three miles above its junction with the Yellowstone we found the valley bottom covered with a thick calcareous crust, the deposits of hot springs, which are now extinct; but flowing swiftly from beneath this crust, is a stream of hot water six feet wide and two feet deep, with a temperature of 132°. A little distance farther up is a group of four placid springs, with nearly circular basins, 6 to 10 feet in diameter, and two to three feet deep. A number of invalids are living in tents near these springs, bathing and drinking the water; and they were enthusiastic in their praises of its curative effects, especially for cutaneous diseases.

The chart accompanying this paper gives the localities and temperature of these springs. Near this last group of springs we ascended a high semi-wooded hill, with here and there a grove of pines. A system of terraces has been formed on the slope of the hill, each from 200 to 300 feet in height, and these terraces were

covered with a thick deposit of lime. The surface of the first and second was fast decomposing, and the springs were nearly extinct. One only reached a temperature of 140°. After ascending the hill among the pines, about three-fourths of a mile from the river bottom, we came suddenly upon one of the most remarkable exhibitions of the hot spring deposits that we have seen in this land of wonders. In the distance it looks like a vast glacier of snow and ice, and on that account we have named it the White Mountain. Indeed the different terraces can be compared for their wonderful beauty only to a frozen cascade. The main portion of the area occupied by these deposits is two miles square, or four square miles, and if the reader can conceive numberless springs flowing out from the mountain side and spreading over the surface, and the water slowly congealing into ice, he may have some conception of the wonderful architectural beauty of these terraces. But let us pass along the west side of this beautiful structure, and examine it in detail. We find, first, a broad flat terrace, on which are plainly visible the remains of once active springs. Old chimneys, irregular openings, like entrances to caverns, which extend beneath the crust, are numerous, and greatly excite the curiosity. How thick this crust is, it is not easy to determine, but it is probably from 20 to 50 feet, and underneath it, it is supposed that the surplus water from the active springs above flows down to the river. A little farther up we come to a series of basin-like pools, varying in diameter from 4 to 8 feet, with water from one to four feet deep, having semi-circular rims most beautifully scolloped; and underneath these rims are rows of small stalactites, with every variety of ornamentation on the surface. These continue for about fifty yards, gradually ascending, when we come to an abrupt declivity of about one hundred and fifty feet, rising in steps formed of these exquisitely moulded pools, of every size and variety. Upon the terrace above are numbers of the active springs, with basins twenty to fifty feet in diameter, some of them with several centers of violent ebullition in the same basin. The temperature of these springs at the point of outflow varies from 150° to 162°. As the water flows from the basin down the declivity from one of the beautiful pools to the other, it loses a portion of its heat, and one may find a bathing pool with any desired temperature.

These beautiful rims are higher in proportion to the steepness of the descent, and the architecture is consequently varied and attractive. Upon this lower terrace, springs are continually dying out and others are breaking out anew, and during the past summer one of them burst through the crust and now has a basin about fifteen feet in diameter. There are also several ex-

tinct geysers, or more properly speaking, springs once spouting, which at this time have entirely ceased. One of these curious cones we called the "Liberty Cap." It is a circular deposit of carbonate of lime 50 feet high, and about 25 feet in diameter at the base, looking in the distance somewhat like a conical column. The layers of deposit are arranged on the almost vertical sides of the cone like the straw on a thatched roof, or hay on a stack. This was probably a continuous spouting spring building up its own basin around it by hydrostatic force, until it reached a certain height, when that force ceased, and it closed itself up at the top in a cone-like point. The water then continued to flow through apertures in the sides until it ceased entirely. There are many examples of these rounded cones.

Upon the terrace, down about midway on the side of the mountain covered with this deposit, the principal portion of the active springs are now located; and here is presented another picture to the eye which transcends any description in words. It is only through the eye that the mind can form any adequate conception of it. Here the wonderful transparency of the water first attracts attention and excites wonder; we looked down into the clear depths and saw with perfect distinctness the minutest ornament upon the inner sides of the basin, and the exquisite beauty of the coloring and the variety of forms baffles any attempt to portray them, either with pen or pencil. And then, too, around the borders of these springs, especially those of rather low temperature, and on the sides and bottoms of the numerous little channels of the streams that flow from these springs, there is a striking variety of the most vivid colors. I can only compare them to our most brilliant aniline dyes. Various shades of red, from the most brilliant scarlet to light purple; also yellow, from deep bright sulphur through all the shades to light cream color; then also various shades of green. All these colors are rendered very vivid by the water. These springs also are full of a kind of vegetation, which under the microscope prove to be composed of Diatoms, among which Dr. Billings discovers Palmella and Oscillaria. There are also in the quiet springs, and in the little streams that flow from the boiling springs, great quantities of a fibrous silky substance, apparently vegetable, which vibrates at the slightest movement of the water, and has the appearance of the finest quality of cashmere wool.

I have mentioned only a few of the attractive features about these springs, which so charm the visitor. There is neither time nor space in an article of this kind to describe all.

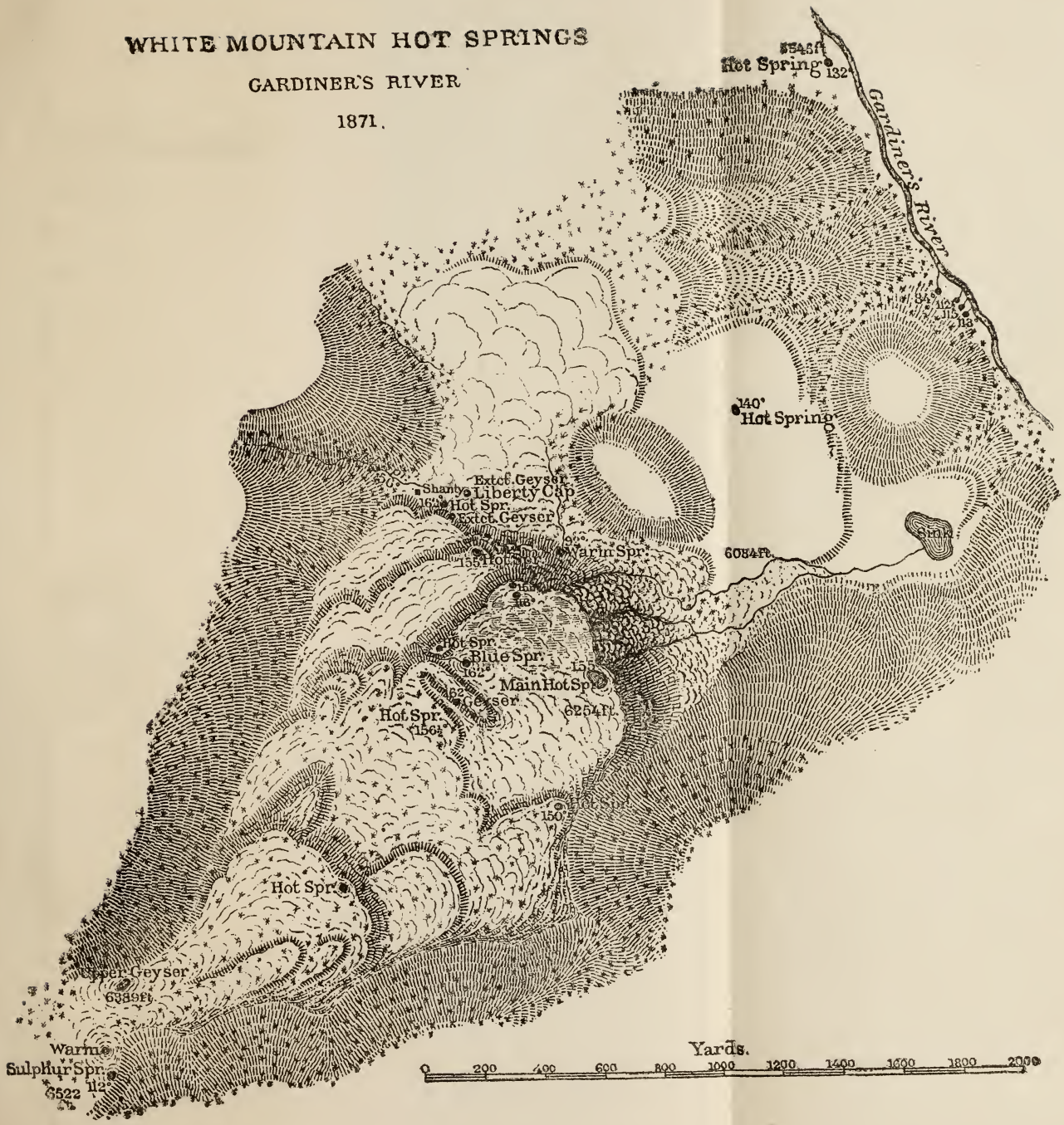
Above this middle terrace are one or two other localities about three hundred feet farther up on the sides of the mountain.

(Plate I.)

WHITE MOUNTAIN HOT SPRINGS

GARDINER'S RIVER

1871.



UPPER GEYSER BASIN

FIRE HOLE RIVER

WYOMING TERRITORY

Surveyed by the Party in charge of

F.V.HAYDEN

U.S Geologist

1871

Scale of Feet

0 500 1000 1500 2000 2500

Magnetic Meridian

Soda Geyser

Fan Geyser

Riverside Geyser

Grotto

Pyramid

Giant

Punch Bowl

Black Sand G

Grand Geyser

Saw Mill G

Castle

Giantess

Bee Hive

Old Geyser Hills

Old Faithful

IRON SPRING CREEK

FIRE HOLE RIVER

Abbreviations

S for Spouting, B for Boiling, M for Mud

Here most of the springs have become extinct, a few occurring here and there on a small scale, where they formerly existed of the largest size. Now the surface is covered with the remains of an exhibition of natural architecture that must have been on even a more beautiful and grander scale than any of the others. Here we find a splendid series of those semi-circular basins, rising in steps to the very summit; but the rich scolloped borders, resting upon rows of stalactites, are now fast going to decay under atmospheric influences. A few small springs send up streams of water in jets two to four feet high. The orifices are lined with a light cream-yellow substance, evidently a mixture of lime and sulphur, covering the sides of the declivity, over which the water flows with this brilliant coating. There are also a number of chimneys, with walls from four to ten feet in height. Some of them are nearly circular at base, with an aperture at top of a foot or more, lined inside with a coating of carbonate of lime, which is hard, smooth and like porcelain in luster. The oblong mounds vary from a few feet to one hundred yards in length, ten to twenty feet in height, and fifteen to twenty feet around the base. These generally have a fissure along the summit, in some of which the waters can be heard seething and boiling like a cauldron. These fissures all have the same beautiful white porcelain lining, and in some of them the brilliancy is greatly intensified by the precipitation of vivid yellow sulphur in acicular crystals, but so delicate that they disappear at the touch. On the east side much of this deposit has been reduced to a fine powder, so that the surface is as white as snow. A qualitative analysis made at the springs, shows that the water contains sulphuretted hydrogen, lime, soda, alumina, and a slight amount of magnesia. Carbonate of lime predominates over all other elements in the deposits, and they may therefore be called calcareous springs.

There are two classes of springs in the Yellowstone valley, one in which lime predominates, the other, silica. With the exception of the White Mountain Springs, on Gardiner's river, and one or two of not much importance, the other springs of the Yellowstone and Firehole Basins are siliceous. They may be divided again into intermittent, boiling and spouting, and quiet springs. Those of the first class are always above boiling point during the period of action, but during the interval the temperature lowers to 150°. Those of the second are always at the boiling point, and some of them throw the water up two to six feet, by regular pulsations. The springs of the third class may have once been geysers, but are now quiet, and have a wide range of temperature, from 188° to 80°. Where the temperature is reduced below 150°, great quantities of the sesquioxide of iron are deposited by the water, lining the inside

of the funnel and covering the surface wherever the water flows. These are designated as iron springs on the chart.

An interesting question now arises in regard to the probable time required for the deposition of this material. The position of the active springs is continually changing. Taken in the aggregate, these springs have been in constant operation during our present period. The center of activity may have removed and returned to its present position several times. I have not the data to estimate with any degree of accuracy the period of any one era of deposition. Around the springs which are now active are dead pines standing from six to eighteen inches in diameter, buried in the calcareous deposit four to six feet. From such evidence as I could gather, I should estimate that under favorable circumstances, at least six feet of the deposit have been precipitated within the space of one century.

There is another interesting feature connected with these hot spring deposits, and that is the great antiquity as well as compactness of some of them. Upon the summits of mountains 1500 to 2000 feet above the river, and having evidently been lifted up by the forces that elevated the whole range, is a bed of regularly stratified limestone, varying in thickness from 50 to 150 feet, very hard, white and yellowish-white, and appearing in the distance like very pure Carboniferous limestone. It is evident that this bed of limestone extended over a large portion of the valley at one time, for immense masses have broken off and are scattered all over the sides of the mountain, even down to the river. Near the margin of the mountain there is a belt a mile long and a fourth of a mile wide, covered with the masses of limestone broken from the main bed. This rock is so hard that it would make excellent as well as remarkably beautiful building material, and could be converted into the whitest of lime. We may ask the question whether the geological structure of this region has anything to do with the calcareous character of this deposit. On the side of Gardiner's river opposite the hot springs, there is a bluff extending about six miles composed of 1500 feet, in the aggregate, of Upper Cretaceous and Eocene Tertiary strata, with some irregular intercalated beds of basalt. A thick bed of basalt upon the summit rests unconformably on the Tertiary beds. This group of strata inclines northeast at a moderate angle. This group undoubtedly extended across the river, southwestward over the area now occupied by the hot springs. Underneath the hot spring deposit beds of older date incline in the same direction, the angle of dip increasing as we ascend the mountains. The entire side of the mountain is covered either with basalt or a thick deposit of local detritus, but here and there we find an outcrop of arenaceous limestones full of Jurassic fossils. We therefore know

that beneath this calcareous deposit there are at least 1500 feet of Carboniferous limestones. If the origin of the heat that so elevates the temperature of the waters of these springs is as deep seated as is generally supposed, then the heated waters have ample play for their powers in dissolving the calcareous rocks beneath.

As a general rule, the groups of hot springs are in the lower valleys, either along the margins of streams or nearly on a level with them. In the case of those just described, Gardiner's river is 5,545 feet elevation, while the summit of the upper terrace, as shown on the chart, is 6,522 feet, so that the upper springs are nearly a thousand feet higher upon the sides of the mountain than those along the immediate margin of the river. Near the head of the East Fork of the Yellowstone there are two or three localities where these calcareous deposits cover limited areas. At one locality near the margin of the stream, there is a very instructive mound, about fifty feet high, with a broad base of 150 feet, rising more gradually to the summit, which is broad, mammiform. The deposit was originally made in thin layers overlapping each other like a thatched roof. This was undoubtedly at one time a spouting spring. It commenced with a very moderate force, nearly overflowing its basin, and building up about 10 feet in thickness of thin, nearly horizontal layers; then it commenced gradually rising until it reached a height of about 50 feet, when it closed itself up at the summit and died out. There is not a sign of water in it at the present time, and none of the springs in the vicinity are above the temperature of ordinary spring water.

We must omit an account of the basaltic columns exposed in the cañons of the Yellowstone and Gardiner's river, and of the great cañons, falls, cascades, and other wonders of this unique region, and pass to the hot springs of the upper basin. A few springs are seen at the mouth of Tower Creek, at the lower end of the Grand Cañon, but it is not until we pass the range of mountains which forms the north wall of the upper basin, about 20 miles above the Lake, that the great hot spring district of the Yellowstone commences. There is here an area, within the drainage of the Yellowstone, 40 miles in length, and on an average 15 miles in width, that either is at the present time, or has been in the past, occupied by hot springs. The old deposits cover the region, and here and there are groups of active springs, mere remnants of what formerly existed. The Grand Cañon is a deep channel 1,000 to 1,500 feet in depth, carved out of the basaltic rocks and hot spring deposits, and on the sides of the walls may be seen the irregular fissures which communicate from the surface with the heated interior. Resting upon an irregular surface of basalt are

(Plate II.)

SULPHUR AND MUD SPRINGS CRATER HILLS

Yellowstone River, 8 Miles below the Lake

immense deposits of silica of all colors, every shade of red, yellow and white; much of the deposit is as white as snow. The remarkable beauty as well as grandeur of the great cañon is largely due to the exquisite delicacy and variety of colors arising from the former action of hot springs.

On the west flank of Mount Washburn there is a remarkable group of springs in a constant state of action at the present time. Alum, sulphur, soda and common salt are found upon the surface in considerable quantities. Sulphuretted hydrogen is emitted from the springs in such quantities as to fill the air, rendering it oppressive with sulphurous odor. This group extends across the Yellowstone to the eastward for several miles. The springs, which are now in active operation, are only a few out of hundreds which once covered the entire area, but which are now dead or dying out.

The two groups, which I will notice next, are called the Sulphur and Mud Springs (see the accompanying charts). The largest group is found on the east side of the Yellowstone, at Crater Hills, eight miles below the Lake. This district covers an area of about half a mile square, and is sometimes called the "Seven Hills," from the fact that there are here several mounds of siliceous deposits from extinct springs, varying in height from 50 to 150 feet. The old craters of dead and dying springs, and the immense quantity of the siliceous deposits, show that the present active springs represent only the last stages of what must have been at some period in the past a magnificent group. Even those which now remain excite intense astonishment. All around the base and high up on the sides of the hill are numbers of vents from which steam is constantly issuing, and around the edges and inside the orifices a layer of sulphur of the most brilliant yellow color has been precipitated. On the west side, one of these jets produces a sound like that of a locomotive, which can be heard for a long distance. The surface is fairly riddled with little steam vents, and the crust sends forth a hollow sound beneath the tread; and on removing this shelly covering at any point, hot vapors come forth, while its under surface is encrusted with the most beautiful crystals of sulphur.

The springs at this point are either boiling, mud, or quiet springs. The principal boiling spring is near the base of the hills, and is in a constant state of violent ebullition, sending up a column of water two to four feet. It has a basin about 15 feet in diameter, and gives forth such a column of steam that I could not approach it except upon the windward side. The rim of this spring is a marvel of beauty. It is composed of silica, but scolloped and covered over with the most delicate bead-work, and upon the pure white silica is deposited a thin layer of sulphur of the most delicate ,cream color. One large quiet

(PLATE III.)

SULPHUR AND MUD SPRINGS

Yellowstone River, 6 Miles below the Lake

turbid spring had a basin of 30 by 50 feet, and a temperature of 163°.

But perhaps the most interesting objects here are the mud springs, which are of every size, from an inch in diameter to twenty feet. One of the largest has a basin about 20 feet in diameter, and is filled with fine light-brown mud, which is in a constant state of agitation, the surface covered all over with puffs like hasty pudding. Others send forth a thud-like noise every second, with an impulse at longer intervals that throws the mud up several feet. The water in the vicinity, as well as the mud, seems to be thoroughly impregnated with alum; a small stream that flows from this group of springs is called Alum creek. In the valley of this stream are hundreds of little mud or turbid water vents, which keep up a simmering noise, showing the nature of the earth beneath the crust. Several of our party broke through the thin covering, and were severely scalded by the hot mud.

Two miles above, on the same side of the Yellowstone, is another group of springs, which, like those just noticed, are boiling, turbid, placid or mud springs. Besides, there are the geysers, to which I will just allude. One of these is a true intermittent spring, and throws up a column of water ten feet in diameter, for fifteen to thirty feet. The crater becomes filled with boiling water; suddenly immense columns of steam shoot up with a rumbling noise, the water overflows the basin, and then a column of water is thrown up for the space of ten or fifteen minutes, when it quiets down and the basin is nearly empty. This operation was performed eight times in twenty-six hours. Upon the side of the hill bordering the river is one of the most terrific mud cauldrons we saw during the trip. A large column of steam is constantly ascending, 500 feet or more, from a deep funnel-shaped basin, 25 feet in diameter; when the wind carries away the steam for a moment, the thin black mud may be seen about 20 feet below the rim in the most violent state of agitation, with a noise like distant thunder. The ground as well as the trees for a horizontal distance of 200 feet around were covered with the mud which had been ejected at some of its periodical outbursts. It would require a volume to describe these springs in detail.

[From the American Journal of Science and Arts, Vol. III, March, 1872.]

In an article, in the February number of this Journal, we closed with a brief description of the mud springs six miles below the Yellowstone Lake. The term Yellowstone Basin is sometimes applied to the entire valley; but the basin proper comprises only that portion enclosed within the remarkable ranges of mountains, which give origin to the waters of the Yellowstone, south of Mount Washburn and the Grand Cañon. The range, of which Mount Washburn is a conspicuous peak, seems to form the north wall or rim, extending nearly east and west across the Yellowstone, and it is through this portion of the rim that the river has cut its channel, forming the remarkable falls and the still more wonderful cañon. This basin is about forty miles in length from north to south, and on an average thirty miles in width from east to west. From the summit of Mount Washburn a bird's eye view of the entire basin may be obtained, with the mountains surrounding it on every side, without any apparent break in the rim.

This basin has been called, by some travelers, the vast crater of an ancient volcano. It is probable that during the Pliocene period, the entire country drained by the sources of the Yellowstone and the Columbia was the scene of as extensive volcanic activity as that of any portion of the globe.

* The charts accompanying these articles were prepared by Mr. E. Hergesheimer, a most accomplished topographer connected with the U. S. Coast Survey.

It might be called one vast crater made up of thousands of smaller rents and fissures, out of which the fluid interior of the earth fragments of rocks and volcanic dust have been erupted in unlimited quantities. Hundreds of the nuclei or cones of these volcanic vents are now remaining, some of them rising to a height of ten thousand to eleven thousand feet above the sea. Mounts Doane, Langford, Stevenson, and more than a hundred other peaks, may be seen from any high point on either side of the basin, each of which was once a center of eruption. Indeed the hot springs and geysers of this region are only the closing stages of that wonderful period of volcanic action, which began in Tertiary times. In other words, they are the escape-pipes or vents for those internal fires which were once so active, but are now gradually dying out. The evidence is clear that, ever since the cessation of the more powerful volcanic action, these springs have been the escape pipes, and have been declining to the present time, and will continue to do so until they entirely cease. The charts accompanying these articles will enable the reader to form a clear conception of the position and number of the most important springs in this basin; but an equal number of the dead and dying springs have been omitted.

Even at the present time there are connected with these manifestations of internal heat, earthquake phenomena, which are well worthy of attention. While we were encamped on the northeast side of the lake, near Steamboat Point, on the night of the 20th of July, we experienced several severe shocks of an earthquake, and these were felt by two other parties, fifteen to twenty-five miles distant, on different sides of the lake. We were informed by mountain men, that earthquake shocks are not uncommon, and are, at some seasons of the year, very severe; and this fact is given by the Indians as the reason why they seldom or never visit this portion of the country. I have no doubt that if this region should ever be settled and careful observations made, it would be found that earthquake shocks are of very common occurrence.

The lake itself is about twenty-two miles long and averages ten or fifteen miles in width. Our soundings show it to have an unusual average depth, though the greatest depth which we were able to find, after a careful series of observations, was about three hundred feet. It is fed by the snows that fall upon the lofty ranges of mountains that surround it on every side. It is the most beautiful sheet of water I have ever seen in the West. The clear green shading, with the deep ultramarine hue of the waters, adds not a little to the effect of the scene. The lake has, at all seasons, nearly the temperature of cold spring water. Its height above the sea level is about 7,427 feet. We were able to discover but one species of fish, a trout weighing from

one to three pounds each. They are very abundant; but five out of six of them were infested with a singular parasitic worm, which is found in the abdominal cavity, or interwoven in the muscular portions in sacs or cysts, or sometimes in the gills. Dr. Leidy has described these worms under the name of *Dibothrium cordiceps*. It is possible that this diseased condition of the fish is caused by the proximity of the hot springs, which are abundant all around the shore of the lake and sometimes extend far out into the waters.

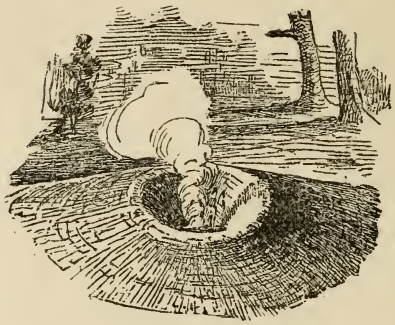
We cannot at this time present a full description of a lake which would of itself furnish the material for an extended article. We may remark, in passing, that we regard the lake basin as due in part to erosion. All along its margin are high banks and terraces composed of a modern stratified deposit, passing up into an aggregation of sand, pebbles, &c., which is not unfrequently cemented into a tolerably firm conglomerate. These deposits, which are made up of eroded volcanic rocks, have in some instances the white appearance, and somewhat the composition, of the Pliocene clays, marls and sands of the other lake-basins along the Missouri and the lower Yellowstone. In the northern portion of the basin, these deposits reach a thickness of three hundred to six hundred feet, and must be of the later Pliocene age, and perhaps extended down to the present time. The two lakes were then connected, although probably never completely united. The belt of mountains that separated them was about four miles in width. I have estimated that, since the period of volcanic activity, the depth of the lake has been about five hundred feet greater than at present, the shore line being then high up on the sides of the surrounding mountains. During the time of the greatest volcanic action, the waters must have covered the loftiest peaks; for many of them are composed of the breccia or conglomerate in a regularly stratified condition. This breccia surrounds the highest volcanic cones or nuclei, as Mounts Doane, Stevenson, &c. The area occupied by the lake is now gradually but very slowly diminishing.

On the shore of the southwest arm of the lake is an interesting group of hot springs, which extend along the margin, covering a belt about three miles long and nearly a mile in width. These springs have built up a series of beds, or strata, about 25 feet thick, in the aggregate, composed of laminæ of silica, which have been worn into a bluff wall by the waves. The shores are covered with the decomposed siliceous crust, so that it looks as if it were covered with the fragments of washed sea-shells.

Many of the springs, which might be called pulsating springs, are in a constant state of quite violent ebullition, but rise and fall every second or two, and, with each pulsation, throw out a small quantity of water. Quite a pretty symmetrical funnel-

shaped crater is formed with a circular rim varying from a few inches to several feet in diameter. Some of these funnel-shaped

1.



Hot Spring.

chimneys extend out into the lake several feet, and the hot spring deposits may be seen through the clear depths for fifty yards. Bubbles may be seen on the surface of the water some distance from the shore in many spots and show the presence of a spring beneath.

The same variety of colors, quiet springs, mud springs, old ruins, &c., that we have before described, occur here. No geysers were observed, but the group of mud springs keep up a constant thud-like noise, which can be heard with great distinctness for half a mile.

On the east and northeast sides of the lake are a number of groups of living or dead springs. High up on the sides of the mountains are two quite extensive patches of the siliceous deposit, which look in the far distance like an immense bank of snow. They are called by the mountaineers, brimstone basins. The large double basin on the southeast arm was once covered with hot springs, though at the present time, there is no water there with temperature above ordinary spring water. Great quantities of sulphur are mingled with the silica, and hence the name.

At Steamboat Point there are two vents which keep up a constant pulsating noise like a high-pressure engine on a river steamboat. Columns of steam are thrown out at each pulsation to the height of 100 feet or more. Hundreds of small simmering vents are scattered all around; dead and dying springs in great numbers can be seen along the shores of the lake, and high up among the foot hills of the mountains, a mile or two from the lake. One of the most conspicuous of these great white hills, seen from all sides of the lake, is called Sulphur Mountain: it is located on the side of the mountains at the north end of

the lake. The summit of this deposit rises about 600 feet above the lake; it is the remains of one of the most interesting group of springs in the vicinity; there are now many steam vents lined with a brilliant coating of sulphur. The deposit is from 50 to 150 feet in thickness, and when not mingled with sulphur, is as white as snow. Silica predominates over all other materials; but it is much variegated by oxide of iron, sulphur, &c. At the foot of the mountain, near the margin of Pelican Creek, a few springs issue from beneath the crust with a temperature from 150° to 180°, but this great group may now be regarded as extinct.

We will now leave the Yellowstone Basin, and, pursuing a westerly course, make our way over the high range, or divide, into the great Geyser Basin of the Firehole river, a branch of the Madison Fork. The mountains that surround the Yellowstone Basin are of the same character as those which extend down the branches of the Madison and Gallatin Forks for thirty miles; and not until then do the sedimentary or granitic rocks appear to any extent. Immense quantities of obsidian also are found on both sides of the range. Little lakes, varying in size from the diameter of a few hundred yards to four or five miles, are scattered all about the sources of the Missouri, Yellowstone and Columbia. Some of them are situated on the very summits of the mountains, ten thousand and eleven thousand feet above the sea.

Traveling in this region is attended with great difficulties, on account of the fallen timber. The uplands, as well as the lowlands, are covered with a dense growth of pines, the majority of which have a trunk not over six to twelve inches in diameter, but run up to a height of 100 to 150 feet, as straight as an arrow. These pines often grow so thickly together, that, for miles, it is very difficult to find space between them for the passage of our pack animals. Almost every year the autumnal fires rage among these dense forests, destroying the trees; and then come the strong winds that lay them down in every direction. We have traveled for thirty to fifty miles over a perfect network of these fallen pines, from three to six feet high, requiring great ingenuity and labor to make our tortuous way among them.

In crossing the main divide between the drainage of the Yellowstone and the Madison, we first strike the sources of the branch named, on the chart of the Lower Geyser Basin (accompanying this paper), the East Fork. Every few miles we meet a group of dead or dying springs. Very few of these contain much water at the present time, but steam was issuing from hundreds of vents. There was one locality, covering several acres, that presented one of the most beautiful of scenes. The

entire area was covered thickly with conical mounds of various sizes, ranging in diameter from a few inches to a hundred feet or more, and these cones or hillocks were full of orifices, from which streams were issuing. All these little chimneys or orifices were lined with the most brilliant crystals of sulphur, and when the heated crust was removed, we found the underside adorned in the same manner. The basis of the deposit was silica, as white as snow; but it was variegated with every shade of yellow from sulphur, and with scarlet or rose color from oxide of iron. In the distant view the appearance of the whole country may be not unaptly compared to a vast limekiln in full operation. The east branch of the Madison is almost entirely fed by water from the hot springs, and its temperature is 60° or 80° all the time. The vegetation that grows along its branches and in the stream itself is a marvel of luxuriance.

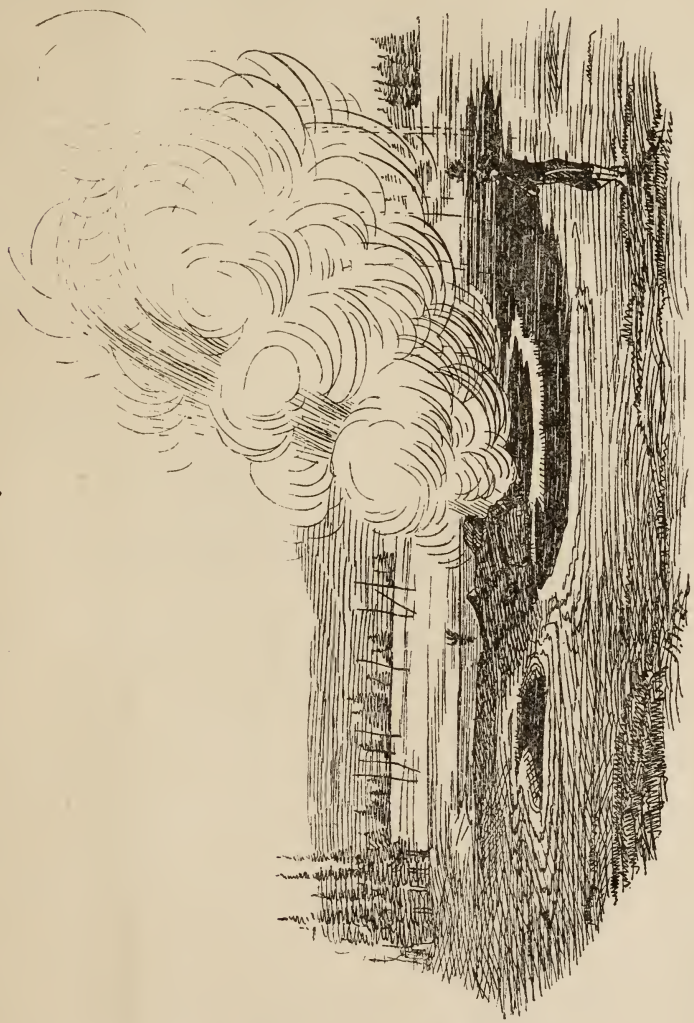
The mountains that enclose the valley on either side are composed of basalt and obsidian. The valley itself, which varies from half a mile to a mile in width, is underlaid with hot-spring deposits. The surface waters pour in abundantly from numerous springs, at the base of the hills on either side, and cover the valley, so that it is one great marsh or bog. Among the foot hills are a number of old ruins, or groups of dead and dying springs, with a few steaming sulphur vents remaining to mark the dying stages.

As we proceed down the valley, toward the junction of the East Fork with the main Madison, the springs grow more abundant, and we soon come to the great basin of the Firehole, in which the most powerful geysers are found.

First, before reaching the valley of the Firehole, there is a large group of springs, on both sides of the East Fork (see chart). Here there are no true geysers, but great numbers of boiling and quiet springs, having basins varying in diameter from a few inches to fifty feet, and temperatures ranging from 100°, to 197° F. The elevation here is such that the boiling point is from 192° to 196° F. Only the more important springs are located on the chart, a large number of dead or dying ones being not considered worthy of attention.

A broken range of hills, forming a kind of ridge, extends down between the valleys of the Firehole and East Fork. Near its terminus it is broken into several isolated butes, which are largely made up of old hot spring material, as well as basalt. Indeed, the igneous rocks on either side of both the valleys show plainly that during the time that the volcanic forces were dying out, the hot-springs were in their most active condition, forming very thick deposits, which made up a large portion of the mountain.

From the large group of springs on the East Fork, we passed, between the isolated buttes, to the valley of the Firehole, where the principal springs and geysers are located. The entire valley, averaging about three miles in width, is covered with the sili-



2 HOT SPRING BASIN.

ceous crust as white as snow. Among the dense pines in the foot hills, and even quite high on the mountain side, a column of steam, rising above the tops of the trees, reveals the location of a spring or a steam vent. As we came out into the level open plain of the Firehole valley, the elevated mounds and

numerous columns of steam revealed to us where the most important groups were located. It will be seen on the chart that all these groups, and nearly all the springs, occur along the valleys of the streams, and for the most part very near their banks. On the east side of the valley are scattered groups of springs, the aggregated waters of which form quite large streams. By the side of the largest stream we encamped for two days, making use of the water for drinking and cooking purposes. Some of these springs have the most beautifully scalloped rims, with the inner and outer surfaces covered over with delicate bead-like elevations. The basins vary in diameter from a few inches to one hundred feet. Some of them have nearly circular rims, with funnel-shaped orifices, and are filled with water up to the very margin, which is so transparent that we could look down into the clear depths for five to forty feet and see the smallest tubercle upon the surface. The funnel-shaped orifice or basin usually extends down until it closes up to a very narrow fissure, and then extends on below to an unknown depth.

In the Lower Geyser Basin, although there are many groups of most interesting springs, none of them can rank as geysers of the first class. Over an area of about three miles in width and five in length, the surface seems to be literally riddled with the orifices of active, quiet, dying and dead springs. There must be, at least a thousand of them; only the most important are noted on the chart. Some of them may be called true geysers having rather regular periods of activity, and throwing up columns of water from two to six feet in diameter to the height of 15 to 30 feet. One geyser, with quite a small orifice, played every fifteen minutes or so, sending up a column of water 20 to 30 feet high. A large number of the springs were in a constant state of violent ebullition, throwing the water up two to four feet. Occasionally an unusual impulse was given to the column, sending it up 10 or 12 feet. One of the most remarkable of the springs in this lower basin had built up for itself a cistern, which for beauty and elaborateness would compare well with those of the springs on Gardiner's river. We called it the *architectural fountain.* The whole basin is about 150 feet in diameter. Near the center is the rim of the spring, which is about 25 feet in diameter; the water is in constant agitation, occasionally spouting up a column of water, like an artificial fountain, and filling up the reservoirs and the sides for a radius of 50 feet or more. The siliceous accumulation made by this spring descends for several hundred feet in innumerable semi-circular steps varying from one-fourth of an inch to two inches in height, and is exquisitely beautiful in all its details. When in active operation a column of water is thrown 30 to 60 feet high, when the waters spread over a radius

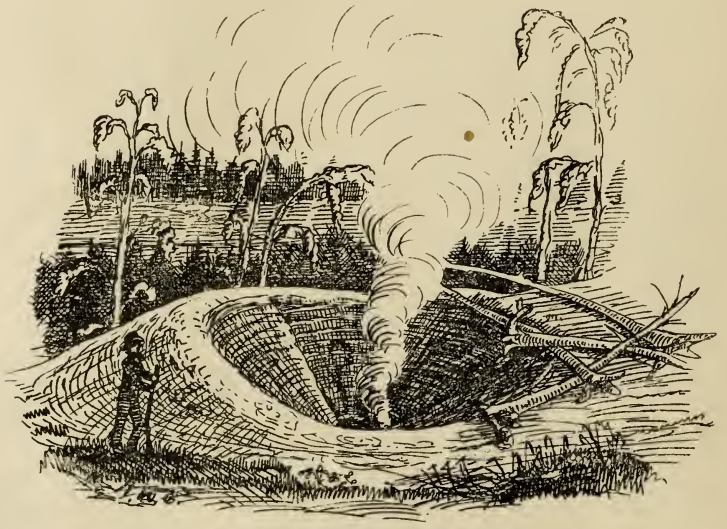
ARCHITECTURAL FOUNTAIN.

of fifty feet, filling the numerous reservoirs that surround the immense rim of the basin. There were other funnel-shaped basins with elegantly scalloped rims, which were covered all over the inner side, to the depth of 10 to 20 feet, with bead-like tubercles of silica. Sometimes these siliceous beads were arranged in large numbers like Fungia corals, or like the heads of cauliflowers.

In the Firehole Basin, silica predominates in the deposit, and so far as we could determine there was very little, if any, lime. Sulphur occurs in very small quantities in the lower basin, although there were two or three springs the orifices of which were lined with it.

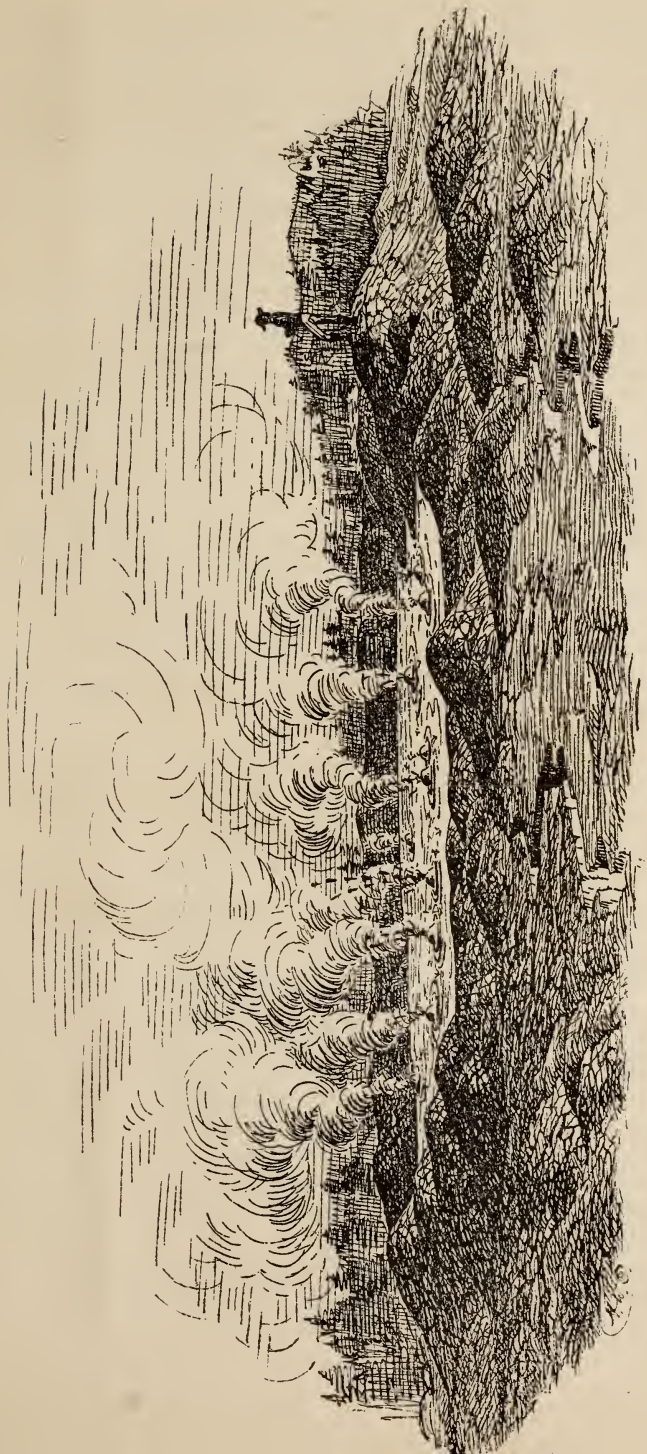
A short distance from this beautiful geyser is a remarkable group of *mud springs.* One of them has a basin fifty feet in

4.



Mud Geysers.

diameter, which is covered over thickly with puffs, like an immense cauldron of thick hasty-pudding. The exact symmetry of these puffs, their uniformity of size and the fineness of the material render them exceedingly beautiful; and there is among them every shade of color, from a bright scarlet to the most delicate pink or rose, with a base as white as snow. The white siliceous clay, when dried, has the appearance of the finest meerschaum. The most fastidious manufacturer of porcelain ware, would go into ecstacies over this magnificent bed of mortar, that has perhaps been worked and re-worked for many thousands of years.



5. Mud Puffs.

These springs occur in small groups all over the basin, and are often in close proximity to geysers or to perfectly clear quiet springs. They are found in every stage, from simply turbid water, through all grades of consistency, to thick stiff mud, through which the gases force themselves with a suppressed thud-like sound. Each of these mud springs probably commenced as a geyser or at least as a boiling spring. The water is at first clear, then becomes turbid, and grows gradually thicker until the heat dies out.

About half of the springs are in the last stage of action. They have been either geysers, or very active boiling springs, as is shown by the character of their basins; but now their temperature is diminished to 150° and all the way to 80°. When the temperature diminishes to 160°, oxide of iron is thrown down, and they become what are marked on the charts as iron springs. A thick coating of a dull iron-rust color is deposited all over the inner side of the basin, and over the surface where the water flows. This coating in the old springs becomes broken up, so that it is suspended all over the sides of the springs like rotten mouldy fragments of leather. The iron is undoubtedly held together by vegetable matter. When these springs entirely dry up, these leathery fragments are blown about the surface in every direction by the winds.

In the vicinity of the active geysers, the surface over which the surplus water from an eruption flows is sometimes covered, to the thickness of two to four inches, with a substance which appears to the touch like jelly or pulp. All over the surface there are irregular depressions with sharp raised edges, like the inner surface of a cow's stomach. The colors are varied, being usually a white base with every variety of scarlet, pink or rose color, with brilliant shades of green.

Another interesting feature was the quantity of incrusted and silicified wood found scattered about the springs. Very frequently the pine trees, which are abundant in the vicinity, have fallen across the basin of a geyser, or an active boiling spring. The wood becomes permeated with the hot water holding silica in solution, and soon becomes like paper pulp. When the spring dries up, the wood remains in the basin thoroughly silicified and incrusted with a coating of silica. The entire cellular structure is permeated with the silica, and the process of petrifaction is most clearly shown. Into one of the large hot springs, about fifty feet in diameter and twenty feet deep, a living pine tree had been blown by the wind, and all the branches, leaves and cones were completely incrusted over and partially permeated by the silica.

Up the Firehole river about ten miles, there is the Upper Geyser Basin, where the great geysers are found.

In the Lower Geyser Basin on both sides of the Firehole, even up among the foot hills of the mountains on either side, are springs in a state of greater or less activity, and upon the very summits of the mountains is here and there a steam vent. But none of the Grand Geysers are found here. For four or five hours in the early morning, this valley presents one of the most interesting pictures that can well be imagined: columns of steam are rising from a thousand vents, completely shrouding the valley as with a dense fog. A view of the city of Pittsburg from a high point would convey some idea of the appearance of this valley, except that in the former case the dense black smoke arises in hundreds of columns, instead of the pure white feathery clouds of steam.

The Upper Geyser Basin is located very near the source of Firehole river, and between it and the Lower Geyser Basin there is an interval of about five miles in which the hills come close to the river on both sides, and the springs occur only in small groups. Although possessing some interest, yet there were so many others in the region that they did not attract much attention. The valley, as well as the bed of the creek, is covered with old deposits, showing clearly that these springs have been successively breaking out, reaching their culminating period of activity, and then dying out, ever since the Pliocene era. Above this woody and rocky interval, the valley again expands, and a branch comes in from the southwest,

6.

Steam Spring and Cone.

which we call Iron Spring Creek, on which are located many more springs, as the chart indicates. This stream receives its name from the vivid yellow and pink clays, on both sides, from mouth to source. Ascending the Firehole, we find the surface, on both sides of the river, covered with a thick siliceous

crust, and completely riddled with springs of every variety. Quiet springs, with basins varying from a few inches to a hundred feet in diameter, are distributed everywhere. Some high pyramidal cones, with steam issuing from the summits, indicate the last stages of what were once important geysers.

Near the center of the basin, which is about two miles long and half a mile in width, there is one of the most powerful geysers of the basin. During our short visit of two days it operated twice. Our camp was pitched within a few yards of it. The preliminary warning was indicated by a tremendous rumbling, which shook the ground all around us with a sound like distant thunder. Then an immense mass of steam burst out of the crater as from an escape pipe, followed by a column of water eight feet in diameter, and rising by steady impulses to the height of two hundred feet; I can compare the noise and excitement which it produced only to that of a charge in battle. This wonderful fountain continued to play for the space of fifteen minutes, when the water gradually subsided and settled down in the crater, about two feet, and the temperature slowly diminished to 150°. There are here two separate basins, one of which is in a constant state of violent agitation, while the other plays only at intervals of about thirty-two hours; and although, so far as the eye could detect, there was a partition of not more than two feet in thickness between them, neither of them seemed to be affected by the operation of the other. The decorations about these springs were beautiful beyond anything I had ever seen in nature. The most delicate embroidery could not rival them in their wonderful variety and complexity. The surface within and without was covered over with little tubercles of silica, which had a smooth enameled appearance like the most delicate pearls; down on the sides of the basin were large rounded masses like corals, formed entirely of silica. There was one spring with a small elevated crater about two feet high, which threw up a small column of water, about twelve feet high, by continued impulses, like the movements of a saw, and thus it received the name of the Sawmill Geyser. There were probably from twenty to fifty geysers of greater or less importance in this valley; and it is quite possible that some of the springs placed in the quiet class operated at times as first class geysers. There were also the Grotto Geyser and Castle Geyser. The crater of the latter is about 40 feet in height, and one hundred and fifty to two hundred feet in diameter at its base; it was built up of thin layers of the silica, which rise, much like steps, to the chimney on the summit, which is about ten feet high. Clouds of steam issue constantly from this chimney, and every few moments a column of heated water is thrown up fifteen to twenty-five feet.

But the most accommodating, and, in some respects, the most instructive geyser in this basin was called by Messrs. Langford

7.

Giant Geyser.

and Doane "Old Faithful." During our stay it operated every hour, throwing up a column of water six feet in diameter from one hundred to one hundred and fifty feet. When it is about to make a display, very little preliminary warning is given. There is simply a rush of steam for a moment, and then a column of water shoots up vertically into the air, and by a succession of impulses is apparently held steadily up for the space of fifteen minutes, the water falling directly back into the crater and overflowing in large quantities. It then ceases, and with a rush of steam for a few seconds closes the display for the time. Words can convey but an inadequate conception of the intense excitement which the scene produces upon the mind.

Night and day some of the geysers are in operation continually, and, at certain periods, several of them perform at the same time.

The two kinds of deposits in these regions, the calcareous and siliceous, have been mentioned in the preceding descriptions. According to analyses by Dr. Peale, Chemist of the U. S. Geological Survey, the springs on Gardiner's river which we call the White Mountain Springs deposit carbonate of lime mostly. There is present also sulphate of magnesia, chloride of lime, sulphate of soda and a little silica. In the deposits of the Firehole Basin not a trace of lime could be detected, but about 85 per cent of silica, 11 per cent of water and the remainder mostly chloride of magnesia; and only a slight trace of lime was found in the water. In but one locality west of the lake, Col. J. W. Barlow found a calcareous deposit. There are, scattered over the great area, about forty by fifty miles in extent, a few patches of the sedimentary rocks, and it is most probable that underneath the deposit of this small group of springs, there are portions of the Carboniferous limestone.

So far as we could ascertain, in all the deposits of the Yellowstone Basin proper, and in the Firehole Basin, silica is the dominant constituent. The springs are, with very few exceptions, and those not important, near the borders of the streams below any beds of limestone. It is quite possible that underneath the vast masses of volcanic material, which compose the mountains on every side, the sedimentary rocks exist, but I am disposed to believe that they occur only in isolated and much restricted patches, if at all.

We may therefore state, in general terms, that the great hot spring region of the sources of the Yellowstone and Missouri rivers is covered with rocks of volcanic origin, of comparatively modern date.

In this article I have been able to present only a few of the wonderful and most attractive features of this unique region. A bill has been introduced into Congress which has for its purpose the setting apart of this wonderland as a great National Park for all time. We have, as a precedent, a similar action with regard to the Yosemite valley, and this noble act has met with the hearty approval of the people. The speedy passage of this bill, which will prevent squatters from taking possession of the springs and destroying the beautiful decorations, will also meet with the cordial approval of all classes. We hope that before this article is published to the world the act will have become a law.

DEPARTMENT OF THE INTERIOR

US GEOLOGICAL SURVEY OF THE TERRITORIES.

LOWER GEYSER BASIN

FIRE HOLE RIVER

WYOMING TERRITORY

Surveyed by the Party in charge of

F.V.HAYDEN

U S Geologist

1871